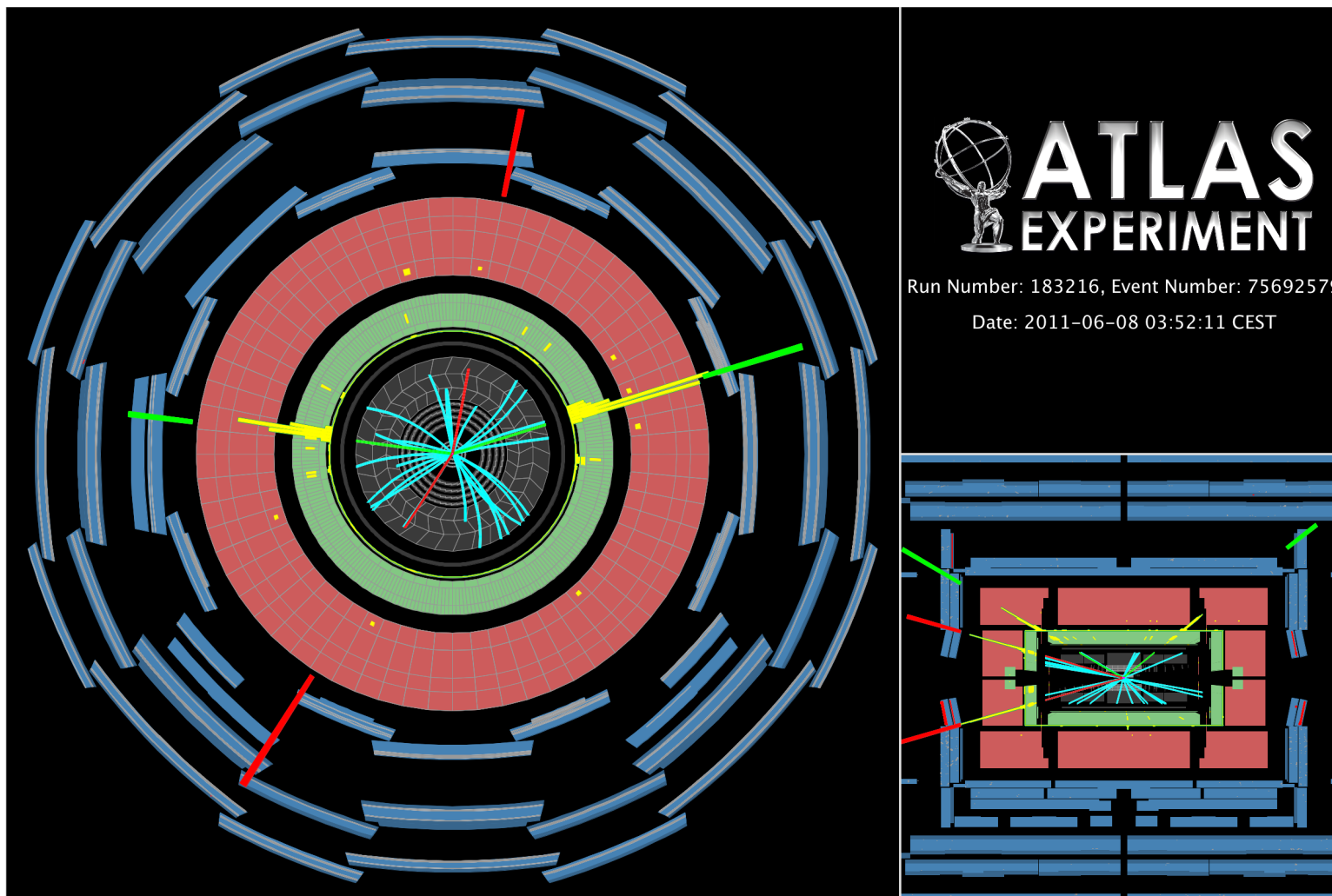


# Searches for New Particles



**Beate Heinemann**

# Introduction

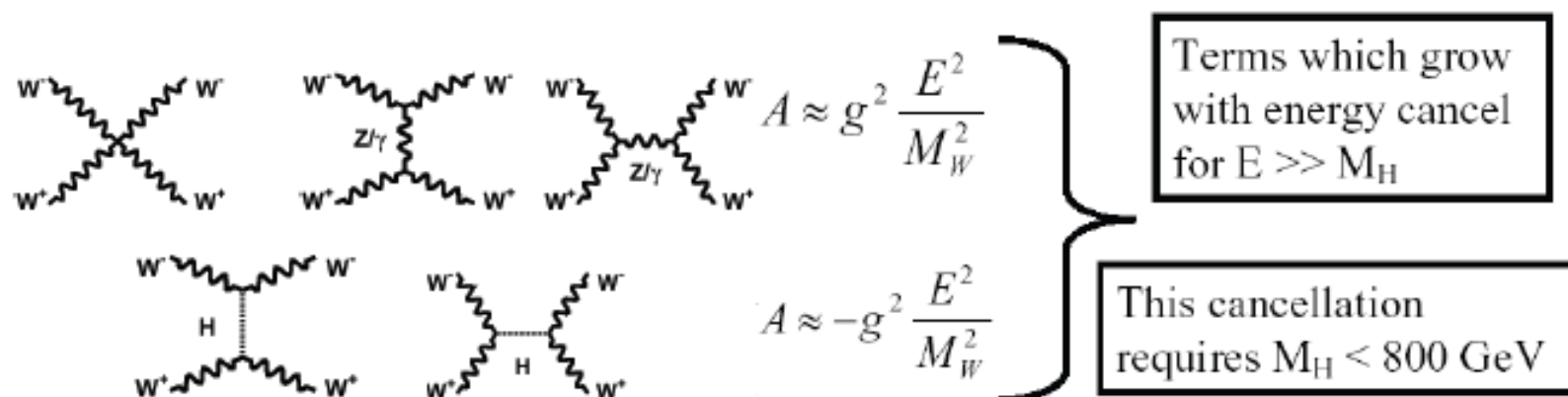
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- The LHC
  - will uncover the mechanism for electroweak symmetry breaking
    - Higgs boson searches, WW scattering
  - might explain the dark matter in the universe
    - Supersymmetry (SUSY) searches
  - might explain why the electroweak scale is so much smaller than the Planck scale
    - Extra Dimensions and SUSY searches
  - might reveal something unexpected
    - generic searches
- LBNL group is involved in aspects of all of these
  - Most results based on 1-5 fb<sup>-1</sup> of 2011 data

# Diboson Production

- Diboson production intimately linked with electroweak symmetry breaking
  - cross section measurements fundamental test of SM
  - probe trilinear gauge boson couplings (TGC's)
  - searches for resonant production



# WZ Production

Hsu, Loscutoff, Shapiro



- event selection

Phys. Lett. B709 (2012) 341-357

- 3 high  $p_T$  leptons (e or  $\mu$ )

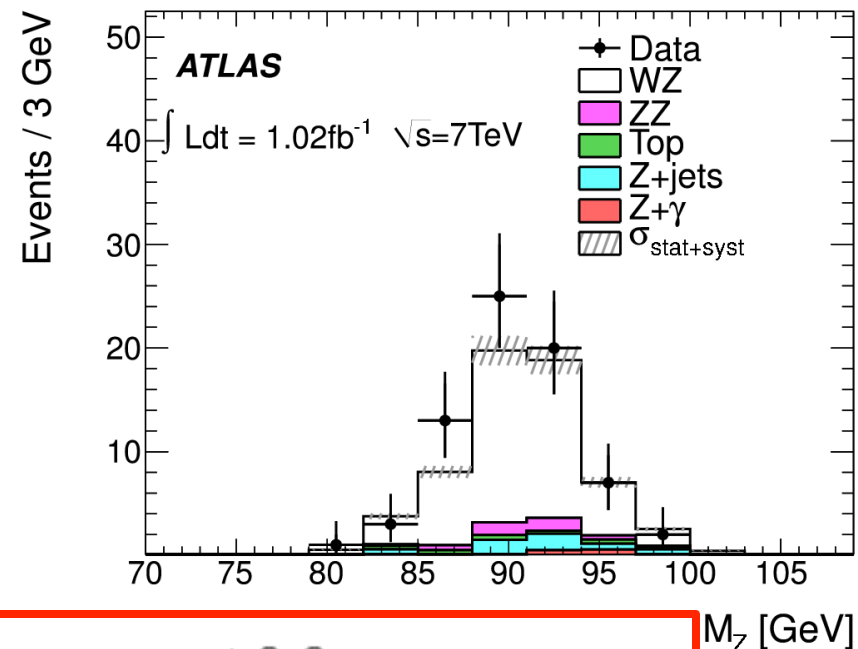
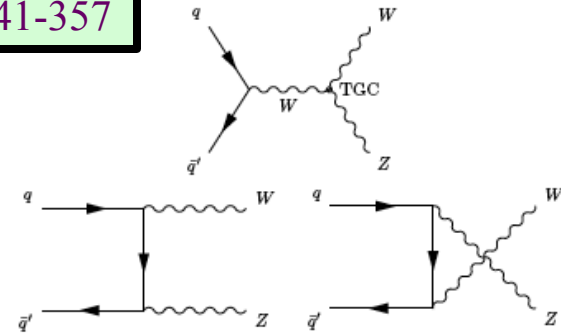
- $l^+l^-$  pair consistent with  $m_Z$

- $E_T^{\text{miss}} > 25$  GeV

- main backgrounds

- W/Z+jets, ZZ, top

process	events
background	12.1
WZ	50.3
<b>Total SM</b>	<b>62.4</b>
<b>Data</b>	<b>71</b>



$$\sigma_{WZ}^{\text{tot}} = 20.5_{-2.8}^{+3.1}(\text{stat.})_{-1.3}^{+1.4}(\text{syst.})_{-0.8}^{+0.9}(\text{lumi.}) \text{ pb.}$$

# ZZ Production

Phys. Rev. Lett. 108 (2012) 041804

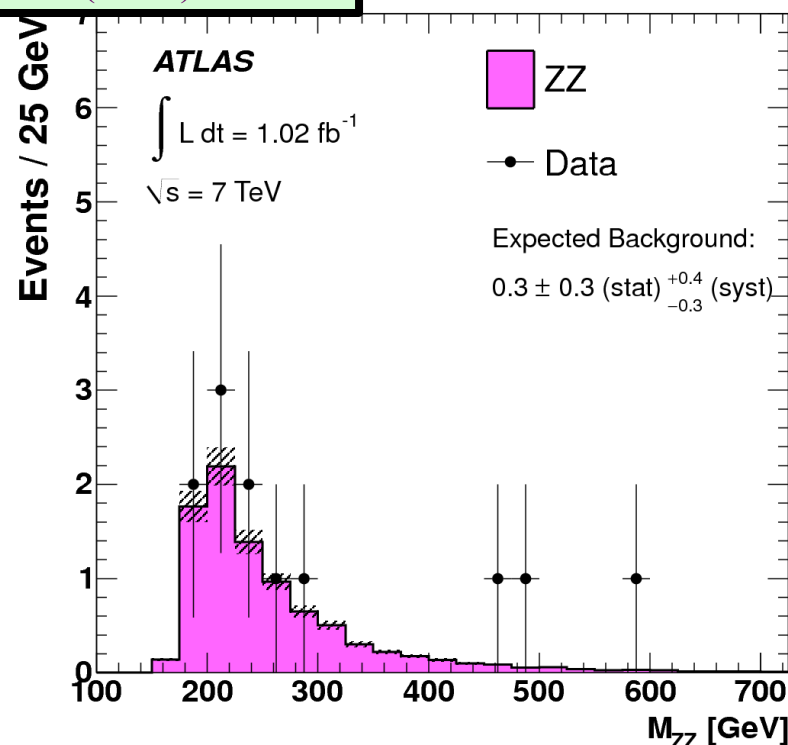
## •Event selection

- 4 high  $p_T$  leptons (e or  $\mu$ )
- 2  $l^+l^-$  pairs consistent with  $m_Z$

## •Main backgrounds

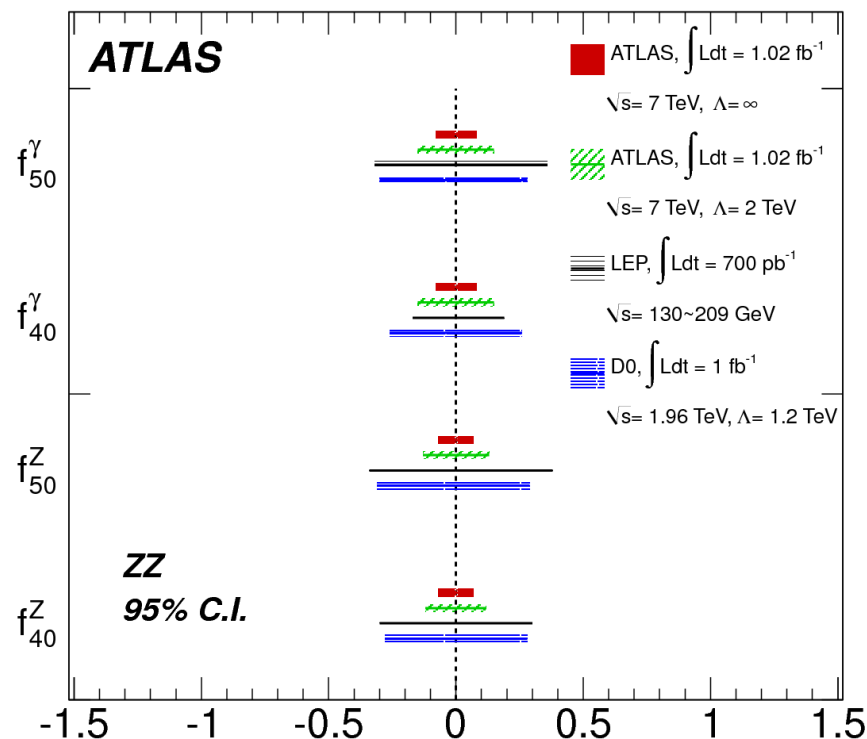
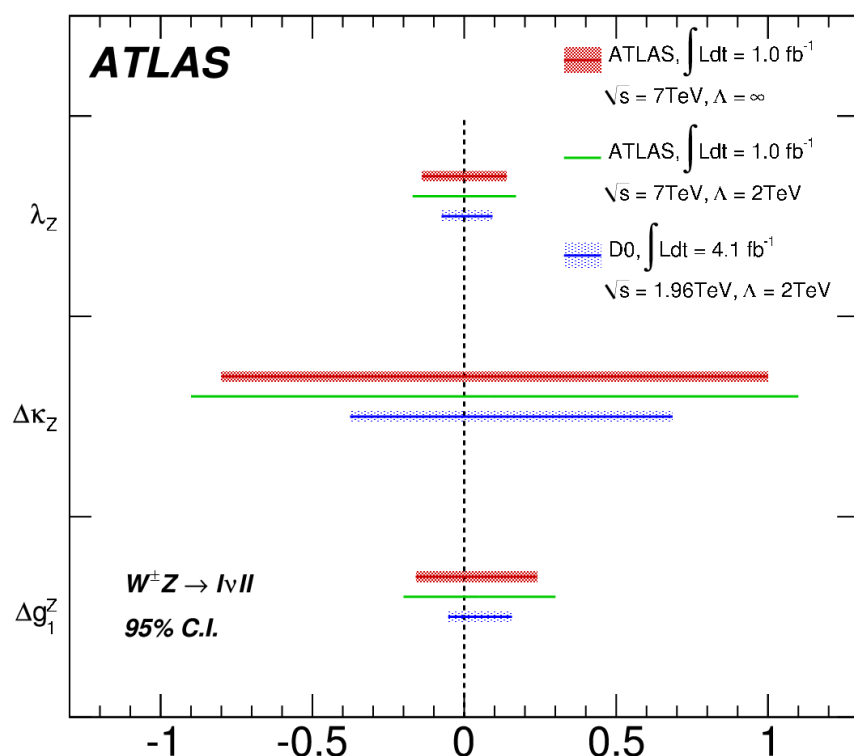
- Fake

process	events
background	$0.3^{+0.5}_{-0.3}$
ZZ	$8.9 \pm 0.3$
Total SM	$9.2^{+0.6}_{-0.4}$
Data	12



$$\sigma_{ZZ}^{\text{tot}} = 8.5^{+2.7}_{-2.3} \text{ (stat.) }^{+0.4}_{-0.3} \text{ (syst.) } \pm 0.3 \text{ (lumi.) pb.}$$

# Trilinear Gauge Couplings

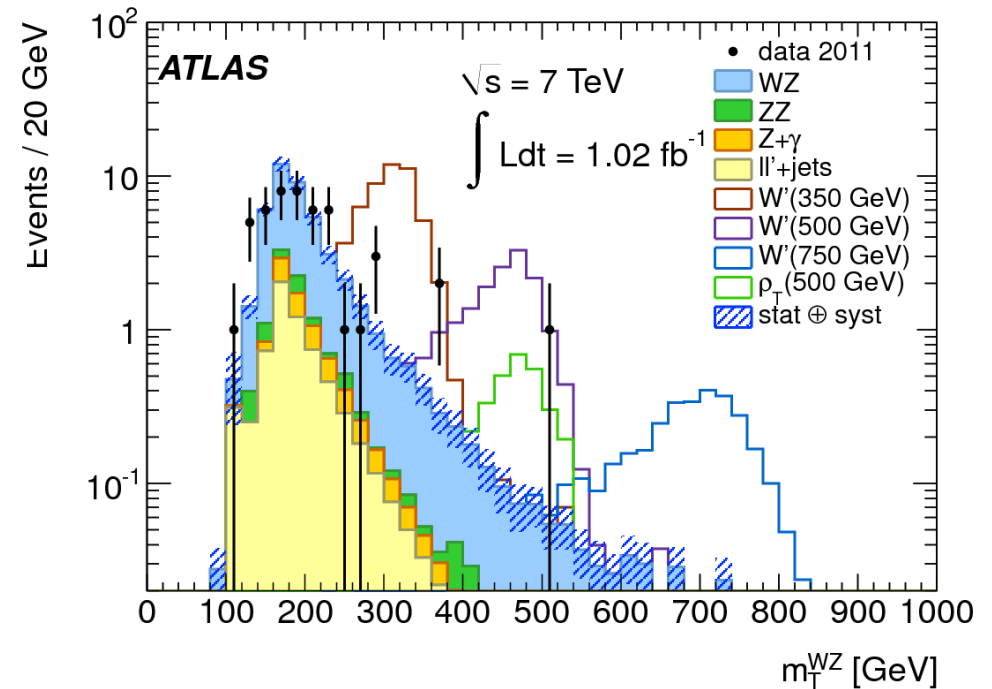
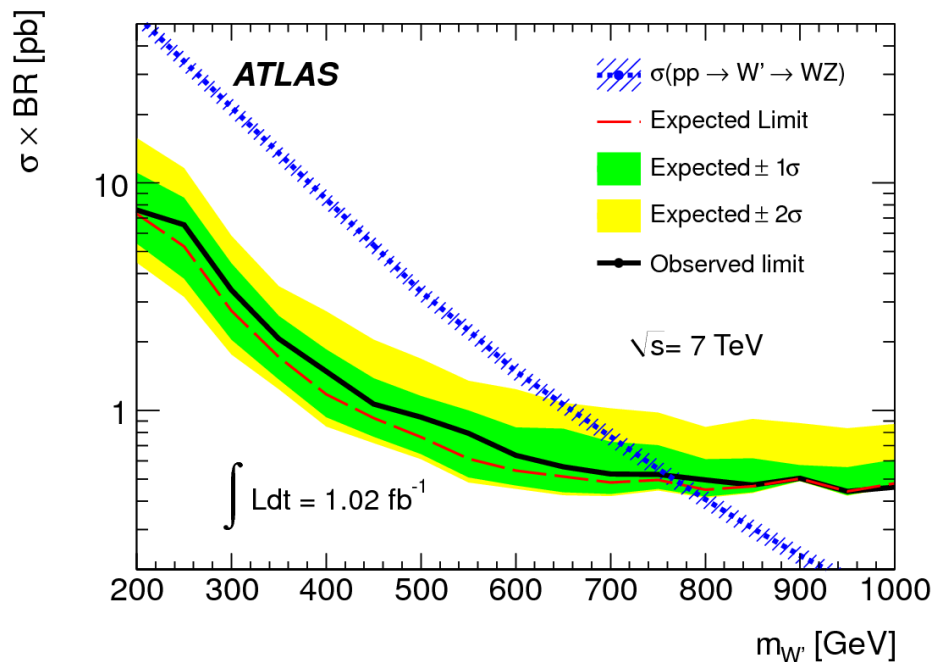


- **WZ analysis on full 2011 dataset also nearly final**
  - Much improved constraints due to usage of differential distribution

# WZ Resonance Search *Hsu, Loscutoff, Shapiro*



- $W'$  or  $\rho_T$  decaying to WZ
- $m_T(WZ)$



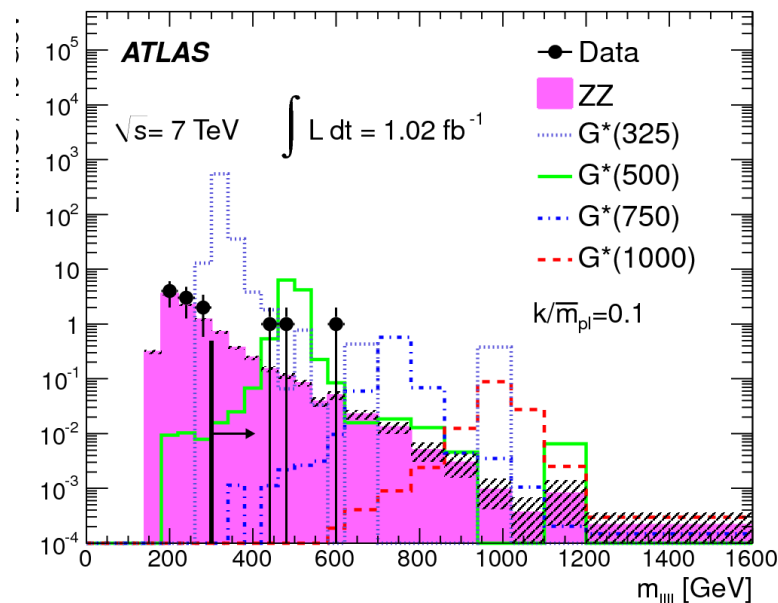
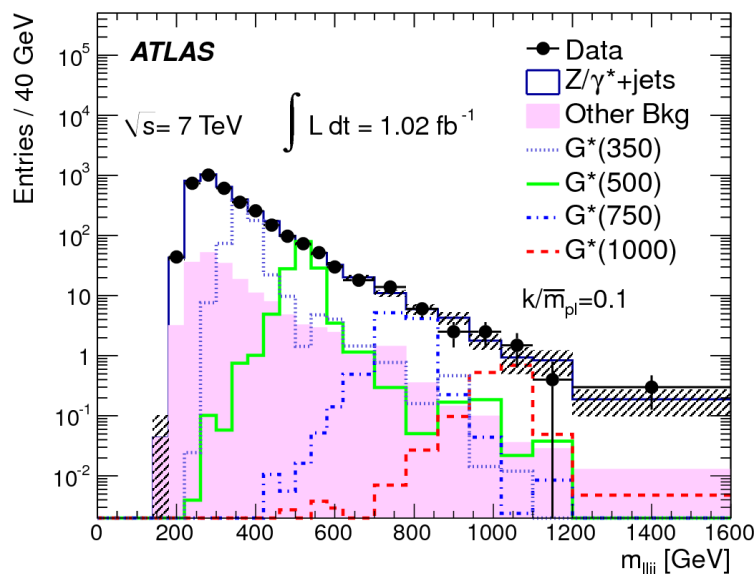
arXiv: 1204.1648 (acc. by PRD)

**$M(W') > 760 \text{ GeV}$  at 95% CL**

# ZZ Resonance Search

- combine 4-lepton search with  $lljj$  search
  - Dilepton and dijet masses required to be consistent with  $m(Z)$

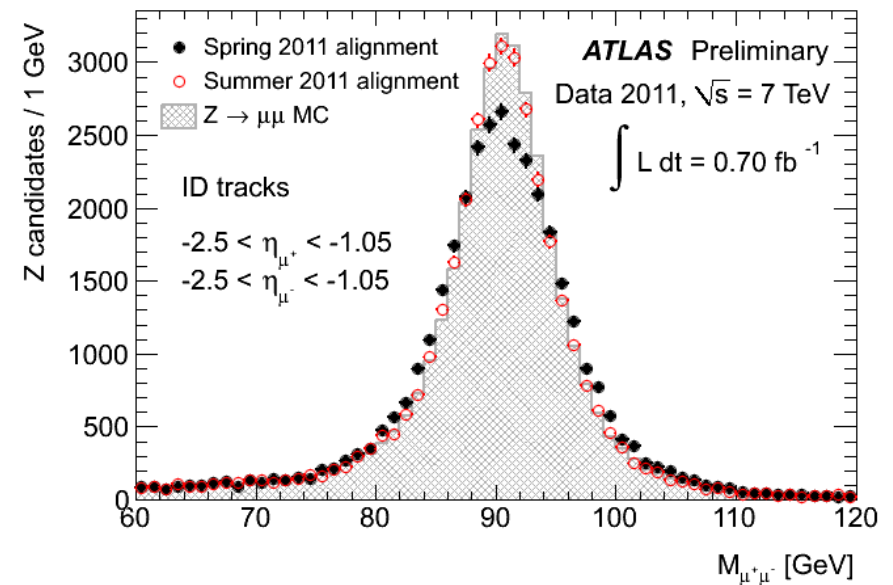
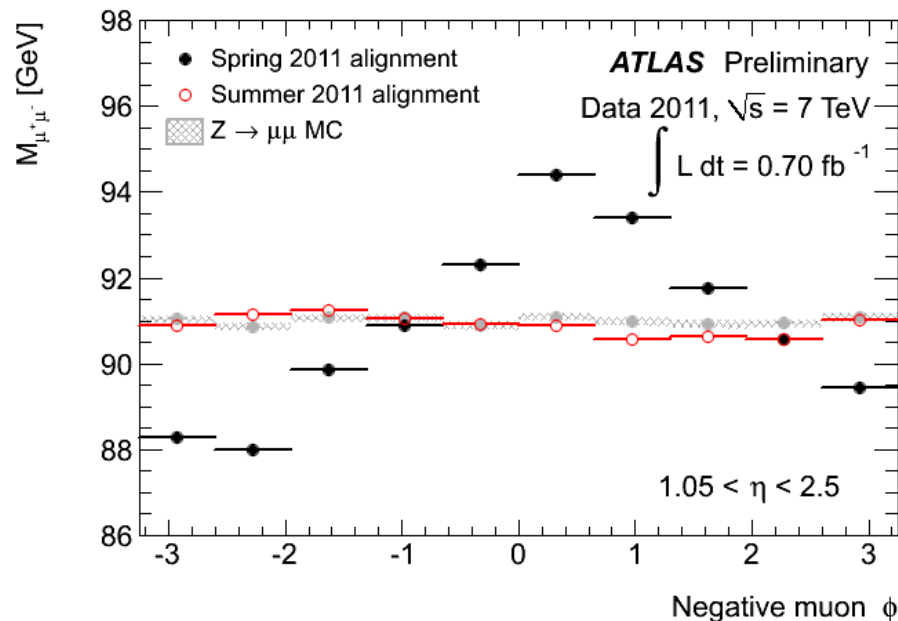
Phys. Lett. B712 (2012) 331-350



- no resonance observed  $\Rightarrow$  constraints on Randall-Sundrum graviton decaying to ZZ

# Inner Detector Alignment

Hsu, Skinnari

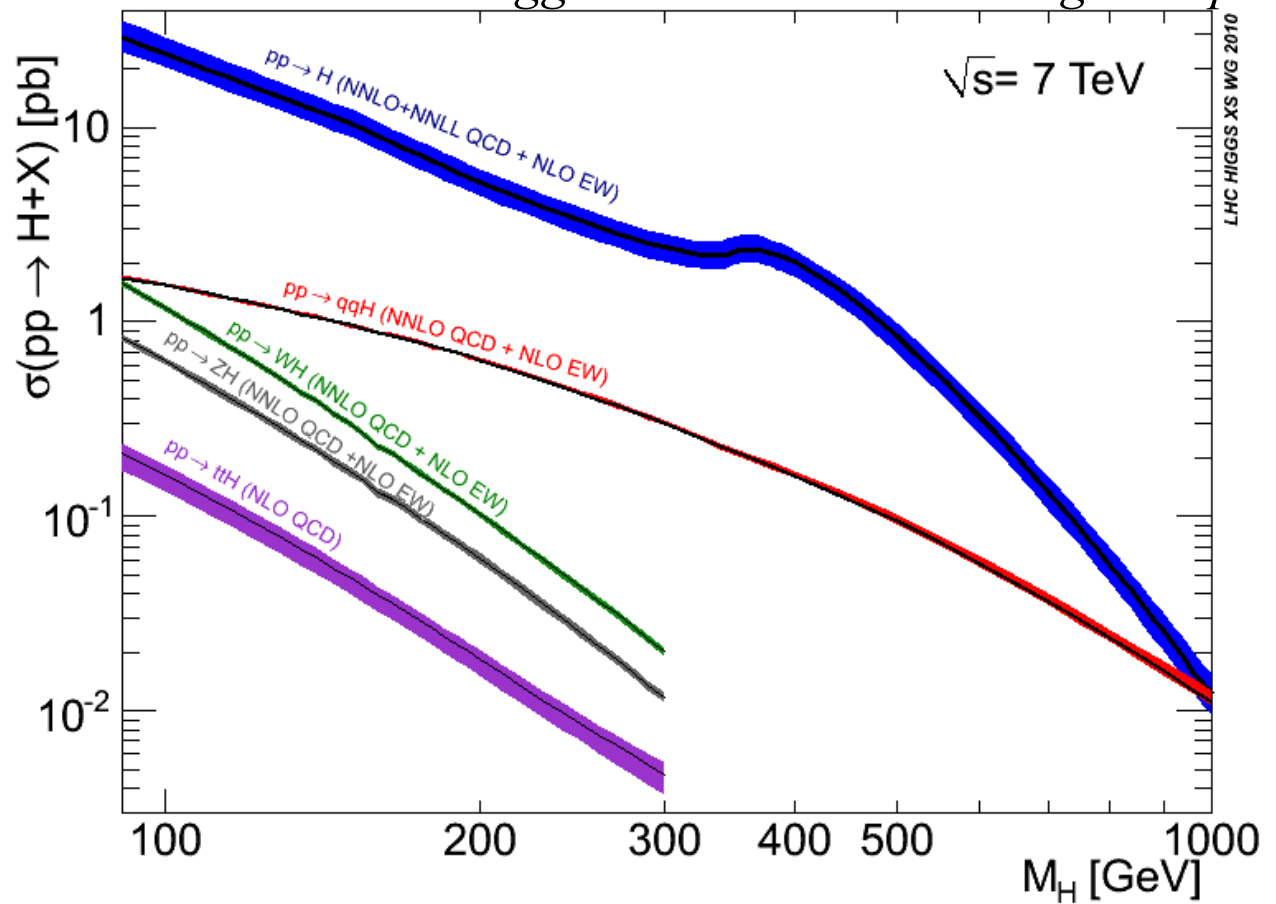
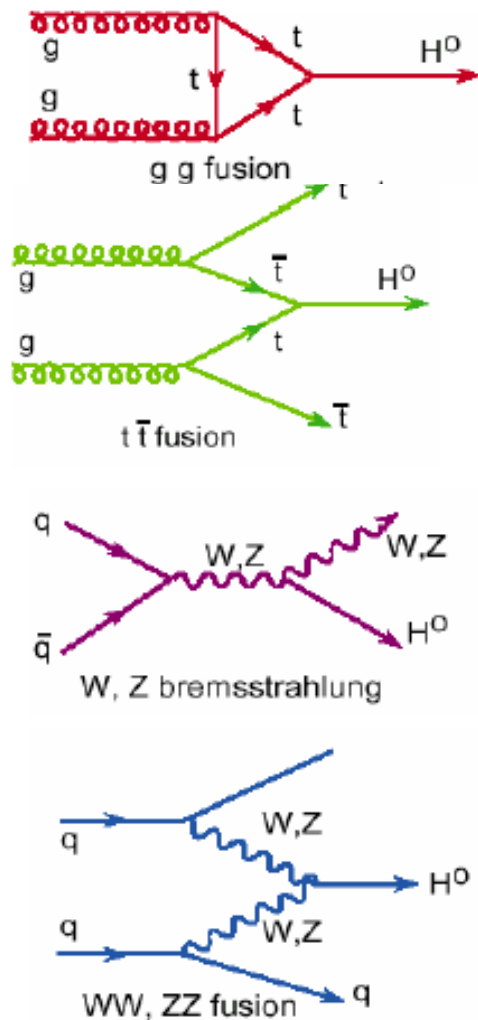


- mass resolution significantly improved due to alignment carried out in summer 2011
  - fixed “weak mode” misalignments in endcaps
  - Data resolution now consistent with simulation

see poster

# Higgs Production at the LHC

*LHC Higgs Cross Section Working Group*

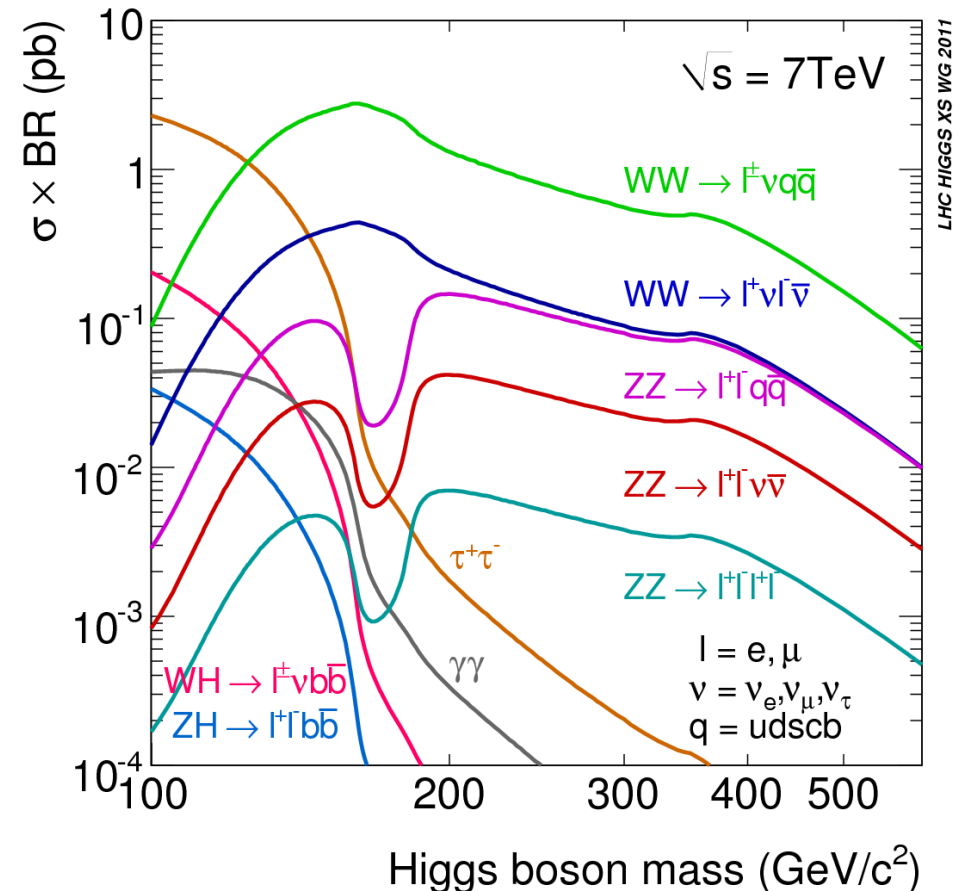


- Cross section uncertainties typically 15%

# Cross Section x Branching Ratio



- **High mass region:**
  - **WW** and **ZZ** most important
- **Low mass region:**
  - **ZZ** → 4 leptons
  - $\gamma\gamma$
  - $\tau\tau$
  - **WW** →  $l\nu l\nu$
  - **bb** (only **WH** and **ZH**)



**LBNL involvement up to now: WW,  $\tau\tau$**   
**(very recently also ZZ)**

# Higgs $\rightarrow \tau\tau$ Search

Clarke, Biesiada,  
Pranko, Varouchas



- 3 analysis channels

  - $\tau_l \tau_l, \tau_l \tau_h, \tau_h \tau_h$

- mass reconstruction

  - Use “MMC” method

    - by Pranko et al.

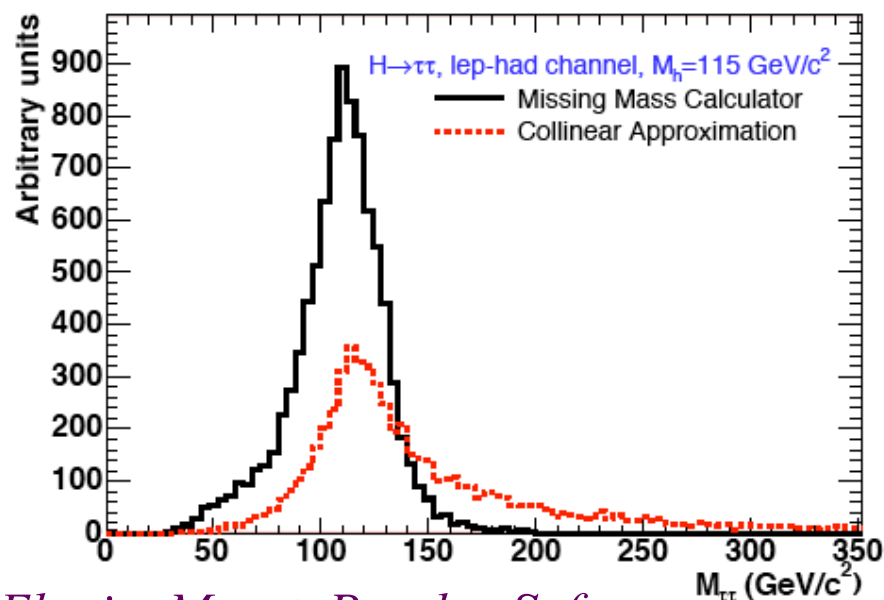
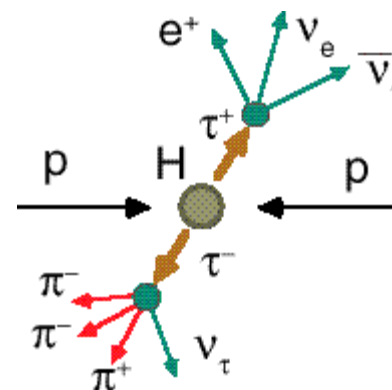
  - Improvement compared to traditional “collinear approximation”

- main backgrounds

  - $Z \rightarrow \tau\tau$

  - $W + \text{jet}$

    - jet misidentified as  $\tau$



Elagin, Murat, Pranko, Safonov

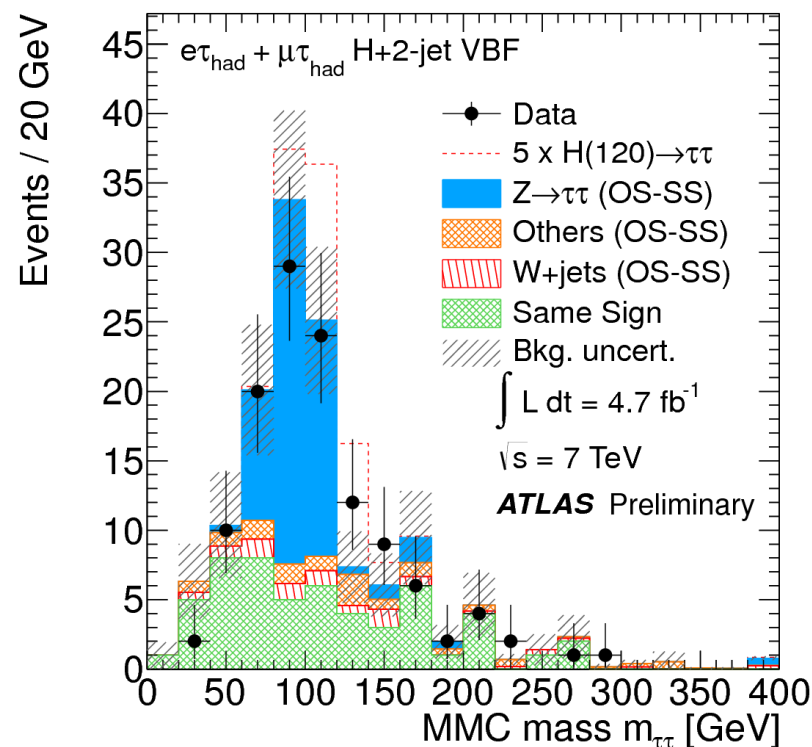
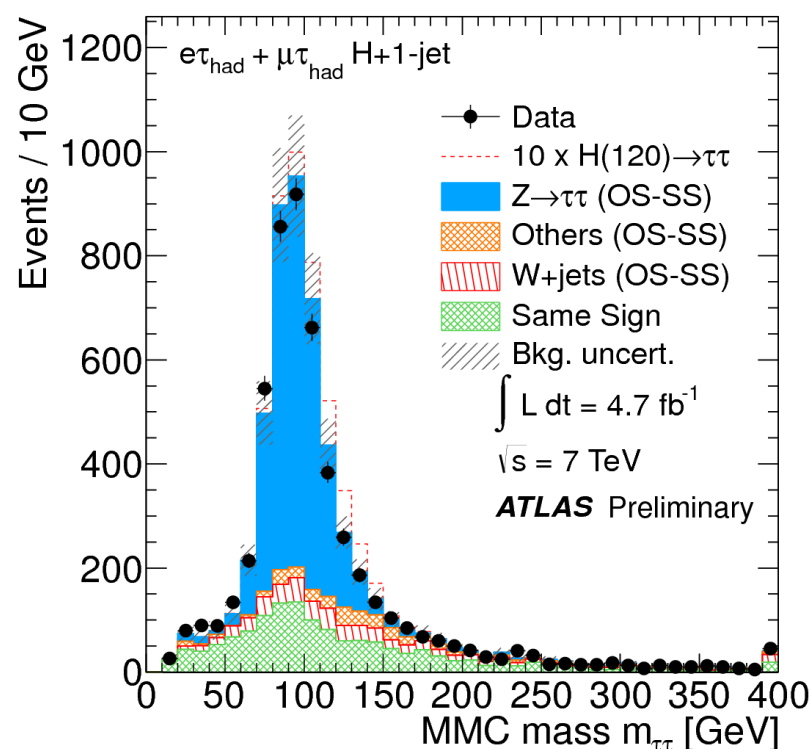
Nucl. Inst. Methods A654 (2011) 481-489.

# Ditau Mass Distribution

Clarke, Biesiada,  
Pranko, Varouchas

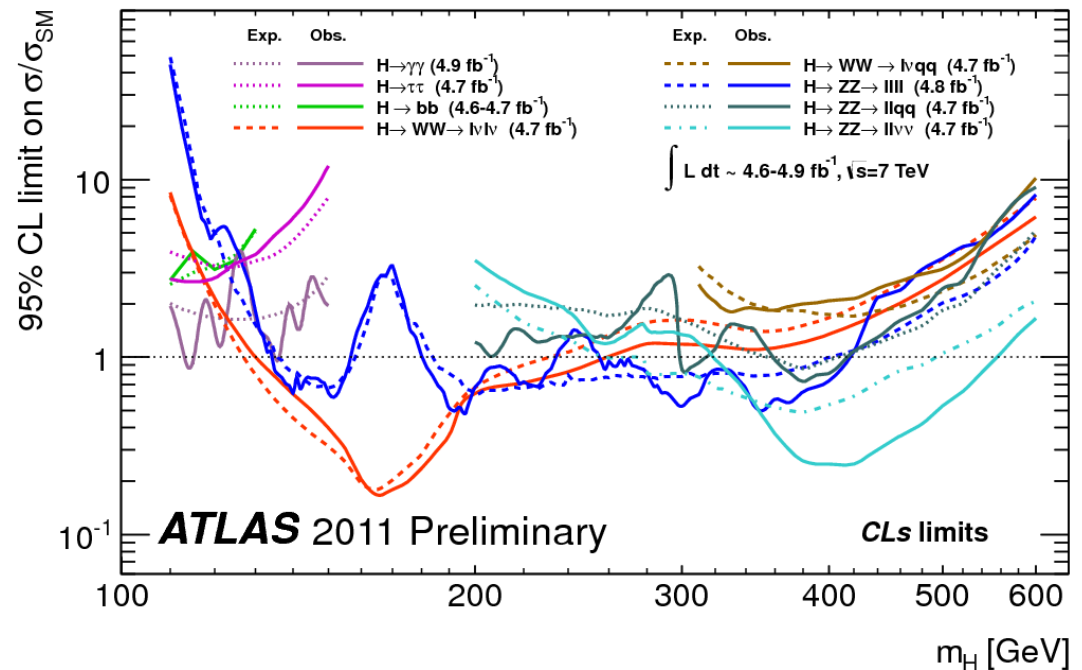
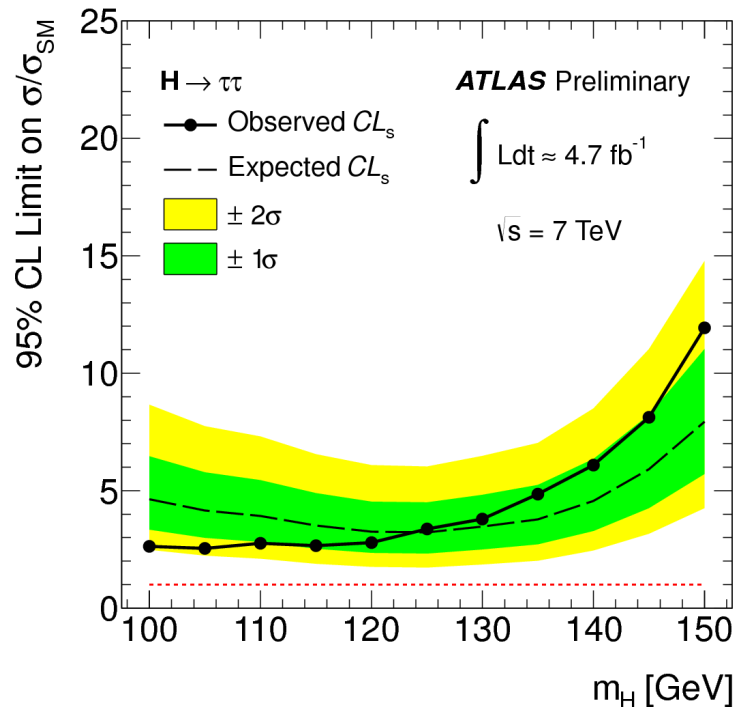


ATLAS-CONF-2012-014



- data agree with background expectation
- sensitive to 5 times the SM Higgs rate in th1l mode
  - Other modes have similar sensitivity

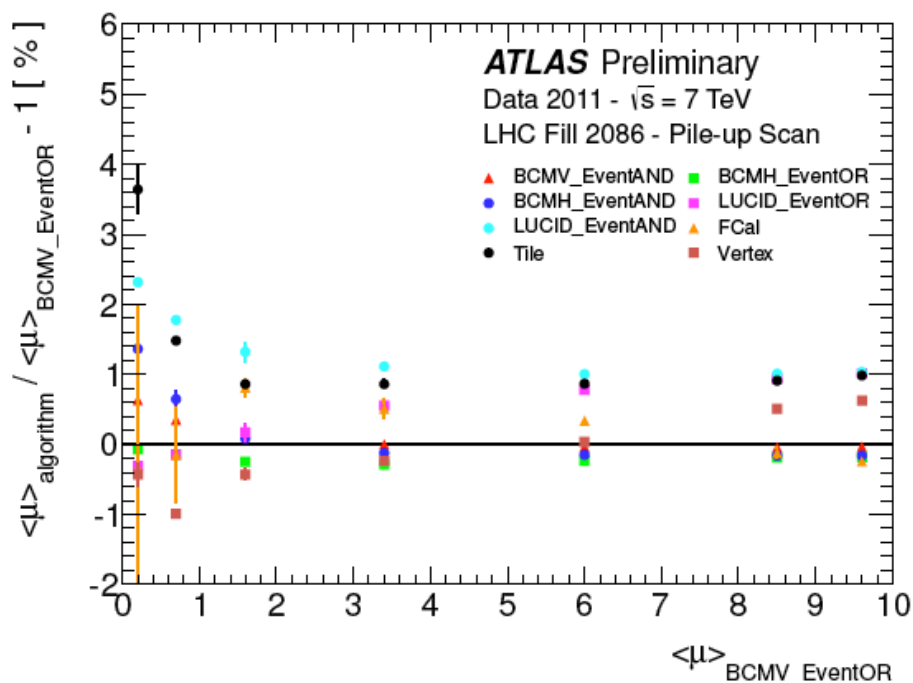
# Higgs- $\rightarrow\tau\tau$ Cross Section Limits



- **Not yet sensitive to SM Higgs rate**
  - Many improvements on the way for 2012 data analysis
- **Observation critical to establish “if it is the Higgs”**
  - Probes directly the coupling to fermions

## • Luminosity measurement critical for all ATLAS analyses

- Cross section measurements
- Searches for new physics



*work in progress*

Uncertainty Source	$\delta\mathcal{L}/\mathcal{L}$	
	2010	2011
Bunch Charge Product	3.1%	0.54%
Other $\nu dM$		
Calibration Uncertainties	1.3%	1.43%
Afterglow Correction		0.20%
BCM Stability		0.25%
Long-Term Consistency	0.5%	0.70%
$\mu$ Dependence	0.5%	0.50%
Total	3.4%	1.78%

## • preliminary uncertainty for 2011: **1.8%**

- Smallest uncertainty ever achieved at hadron collider!

# Black Hole Search

*Dube, Hinchliffe*



- **Extra dimension models present solution to hierarchy problem**

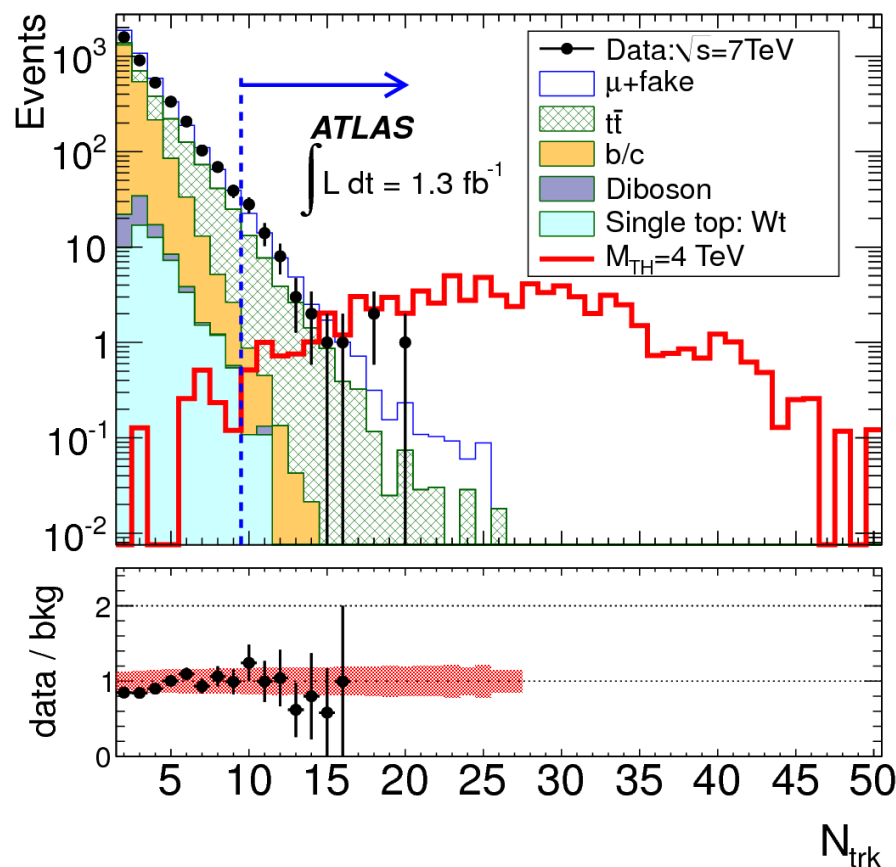
- fundamental Planck scale  $M_D$  a few TeV
- microscopic black holes could be produced

- **Black holes evaporate via Hawking radiation**

- **High multiplicity**

- **Select events with 2 like-sign muons + 8 tracks with  $p_T > 10$  GeV**

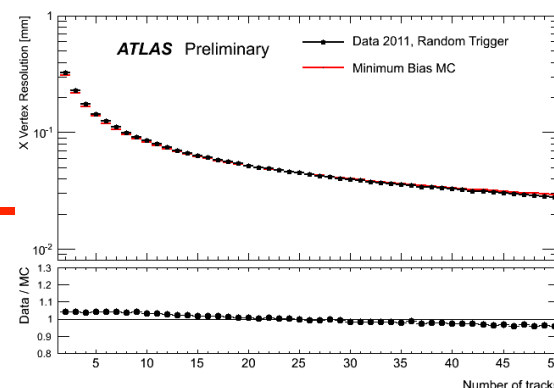
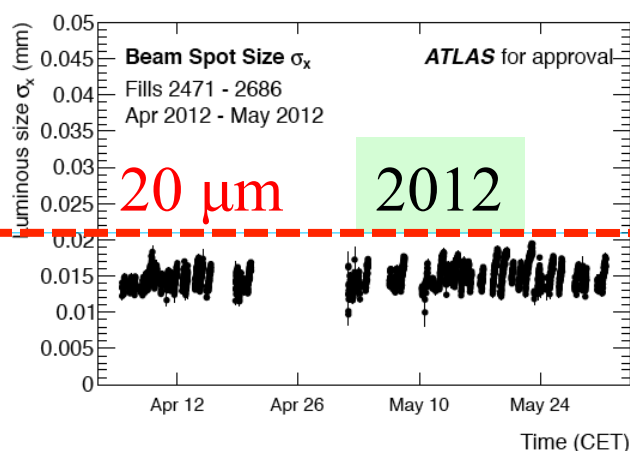
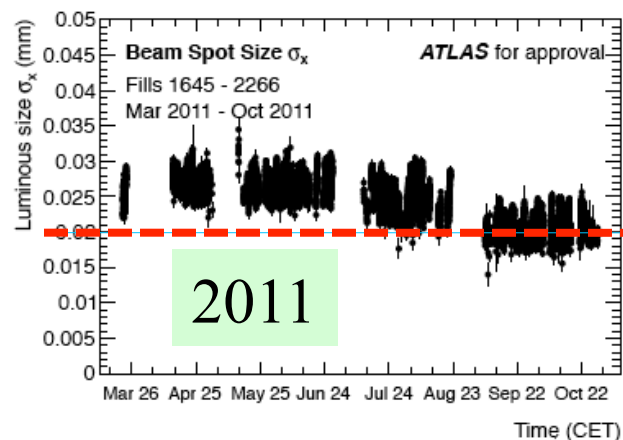
Phys. Lett. B 709 (2012) 322-340



*see poster*

# Vertexing & Beamspot

*Beringer, Hurwitz, Yu  
Loscutoff, Pagan Griso*



- beamspot determination integrated in Tier0 processing since 2010
  - Likelihood extracts positions, widths and correlations
  - Provides important constraint for primary vertexing
- Vertex resolution, efficiency and fake rate understanding important at high pileup
  - Data are well modeled by simulation

# More Search Analyses in progress..



*Arguin, Heinemann, Hurwitz, Skinnari*

- Anomalous production of like-sign dileptons
  - Extension of  $\mu\mu$  analysis including  $ee$  and  $e\mu$  (2011 data)
- Search for gluinos decaying via top quarks
  - signature: like-sign leptons and b-jets (2011 data)

*Copic, Dube, Hance, Heinemann, Hinchliffe*

- Multi-lepton search
  - focus of LBNL group is tau-leptons (2011+2012)

*Galtieri, Pagan Griso, Quayle*

- H- $\rightarrow$ WW search
  - Lowering the subleading lepton  $p_T$  (important for 125 Higgs): 2011+ 2012 data

*Heinemann, Pagan Griso, Sood*

- WW scattering
  - In like-sign WW channel: 2011+2012 data

- Most of analyses mentioned before are being refined and updated with 2012 data

# Conclusions and Outlook

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- **Broad range of searches carried out by LBNL**
  - see also talks by A. Bach and L. Skinnari
  - No sign of new physics in 2011 data
  - Higgs boson search has entered a very exciting phase
- **2012 data analysis has started**
  - Already recorded  $>6 \text{ fb}^{-1}$  of 8 TeV data
- **Many important technical contributions benefit many physics analyses**
  - alignment, luminosity, vertexing and beamspot measurements
    - achieved 1.8% precision on luminosity measurement!
- **Hope to make at least one discovery in 2012 data**